A new Time-of-flight wall for R^3B *

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Introduction and design goals

The beams provided by Super-FRS at FAIR will have higher energies and will be more intense than presently available. The goal of the new R^3B setup is to fully exploit the potential of FAIR beams. With the new super conducting magnet GLAD it will be possible to deflect fully-stripped ions up to the Pb region with energies up to 1 AGeV. Also the detectors of the R^3B setup should be able to scope with the new conditions.

One detector of the setup is the time-of-flight (ToF) wall made of plastic scintillators. The purpose of this detector is the measurement of the time-of-flight and the nuclear charge of the fragments after the reaction in the target. Together with the measured trajectory through a dipole field, the mass of the fragment can be identified. The charge is obtained by precise energy loss measurements of the fragments passing through the scintillators. With the Super-FRS at FAIR it will be possible to accelerate fully stripped beams up to the Pb region and consequently, the new ToF wall should be able to separate charge Z from Z-1 even for heavy fragments. For Pb fragments the energy loss measurements for Z and Z-1 are seperated by 2.4 % and a charge resolution of $\sigma_{\Delta_E}<1\%$ is needed in order to resolve them. Furthermore, since the unreacted beam also hits the fragment wall, the detector must be able to maintain the performance even at high beam rates up to 1 MHz. In order to match the momentum resolution of other parts of the setup the relative time-of-flight resolution should be around 0.1‰. Since the detector is placed typically between 12 and 20 m behind the target the shortest expected flight times are about 75 ns. This results in a required time resolution of $\sigma_t<17$ ps (see also contribution [1] in this annual report).

Although the current version of the ToF wall was successfully used in many experiments in the past, we plan to build a new ToF detector with superior time and energy resolution at beam rates up to 1 MHz. It is not planend to use a completely new detector concept but rather take advantage of the experience collected over the last years and advance the current design.

The detector will have four planes of scintillators and the active part will cover an area of 120x80cm^2. Each plane consists of 43 scintillators with the size 800x27 mm^2 and they are read out with photomultipliers on both far ends. The first two planes will have scintillators with a thickness of 3 mm and the last two planes a thickness of 5 mm, respectively. In this contribution we will focus on the performance of prototype detectors concerning the energy resolution and new readout-electronics at high rates.

* Work supported by FAIR@GSI PSP code: 1.2.5.1.2.1.

Prototype results and developments

In order to test the behaviour of the detector without beam, a test stand with a fast LED was developed (see master thesis of Julian Gerbig [2]). The LED emits light in the same wavelength region as the BC408 plastic scintillator, and the intensity as well as the pulse rate can be varied. In order to obtain realistic conditions, the LED was pulsed in random mode.

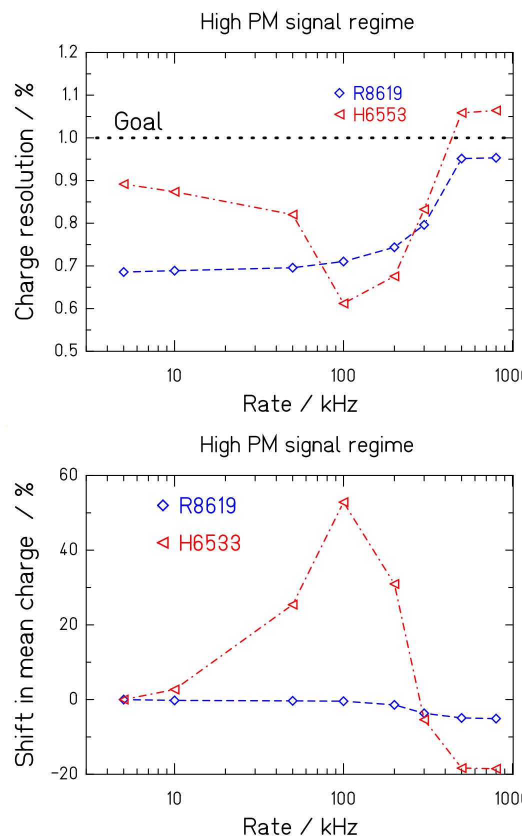

Figure 1: The plot on the top shows the relative charge resolution for each frequency for two differnet PMs. The bottom plot shows the shift in the charge measurments for different rates.

Two different PMs from Hamamatsu were tested, both with a diameter of 1 inch. Model H6533, a very fast PM (TTS: 0.25 ns) but without active voltage divider. This

doi:10.15120/GR-2014-1-FG-S-FRS-04

model was used in the past experiments for the existing ToF wall (NTF). The second model R8619 is a cost effective PM with an active voltage divider (TTS: 1.2 ns).

At the beginning, the conditions of one of the last experiments were simulated. The intensity of the LED was set to simulate medium heavy nuclei, such as e.g. Ni and the voltages of the PMs were set in order to extract large charges as needed for the previously used read-out. The frequency was varied between 5 and 800 kHz. Although the energy resolution for both PMs was good for each individual rate, it was observed that the peak position shifted with frequency (see figure 1). In an experiment with varying beam rate during a spill this would lead to a bad resolution. Especially for the H6533 the shift is dramatic. For the R8619 the shift is much smaller but still visible and too large for resolving charges of heavy fragments.

The shift in the charge measurement stems from the PMs. Especially for large currents, the voltages at the last dynodes can not be kept constant and the gain of the PM is changing. The situation can be improved by taking active voltage dividers and by reducing the HV of the PMs and therefore also the anode current. But also the charge of the signal plays an important role. For small signal charges the R8619 is suited to measure the signals with a resolution (and shift) of less than 1% even for rates as high as 800 kHz as can be seen in figure 2.

It can also be seen that for too small charges, the relative resolution for charge measurements gets worse again. Therefore, for an excellent performance of the new ToF wall is is mandatory to use PMs with active voltage dividers and to reduce the signal amplitudes via the HV of the PMs to a region were the PMs work best with regard to rate stability and charge resolution. This also requires a change in the read-out electronics. So far, CAEN TDC were used and the signals of the PMs were split in a time and an energy branch. The analog signal for the energy branch was delayed by about 600 ns until the trigger decission was made. Especially this long delay caused a damping of the signals by a factor 10. The new read-out will convert the analog signals immediatelly in logic signals with a signal width which is either propotional to the time-over-threshold (ToT) or to the integrated charge (charge to time converter QTC). This signal is then recorded by a multi-event FPGA TDC such as the VFTX2 [3] developed at GSI. From the leading edge of the signal the timing can be obtained (see also contribution [4] in this annual report) and from the trailing edge the energy can be restored. In this way the signal is immediatelly digitized and no delays are needed. Since the VFTX2 is multi-hit cabable the hits can be read out much later.

Summary and outlookents

It is planned to build a new ToF wall for the R^{3}B setup at FAIR. As the existing one, it will consist of plasic scintillators but we aim for an improved energy ($\sigma_{\Delta E}$<1 %) and time resolution (σ_t<17 ps) even at higher beam rates.

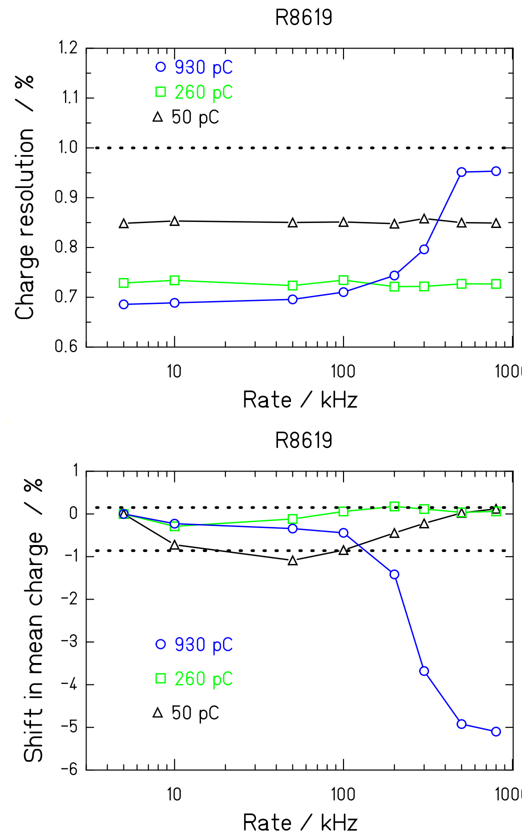

Figure 2: Shown are the charge resolution and the shift in mean energy for the PM R8619 for different loads of the PM. It can be seen that for medium charges (260 pC) a sufficiently good resolution can achieved, even at rates up to 800 kHz.

A test setup with a LED as light source has shown that this is possible with the use of PMs with active voltage dividers and with an adapted electronic read-out which allows to extract only small charges from the PMs. The electronics will be developped by the GSI EE department. We plan to prove the performance of a prototype in beam tests and detail the final layout of the new detector in a TDR.

References

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